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METHOD **AND APPARATUS** FOR RECOGNIZING A STRUCTURE TO BE APPLIED ONTO A SUBSTRATE WITH MULTIPLE CAMERAS~~, AND DEVICE THEREFORE~~

[0001] The present application relates to and claims priority from European Application Serial No. PCT/EP2004/014698 filed December 23, 2004, titled "METHOD FOR RECOGNIZING A STRUCTURE TO BE APPLIED TO A SUBSTRATE, WITH THE AID OF SEVERAL CAMERAS AND EVICE THEREFORE", the complete subject matter of which is hereby expressly incorporated in its entirety.

[0002] The present invention relates to a method for recognizing a structure to be applied onto a substrate with at least one or more cameras~~ in accordance with the generic part of claim~~, and a corresponding apparatus~~ therefore~~.

[0003] For recognizing a structure to be applied onto a substrate it has been customary to carry out optical measurements. Frequently~~, whereby frequently~~ various systems for fully automatic testing of the structure, including adhesive and sealing agent lines, are used.. ~~for this purpose.~~ For this purpose, multiple video cameras are directed at the structure to be recognized. In ~~, whereby, in~~ addition, an illumination module serving to generate a contrast-rich camera image is required.

[0004] In order to be able to monitor an adhesive line ~~and/~~or adhesive trail while the structure ~~it~~ is being applied, it is necessary to teach-in a reference adhesive trail (~~,~~i.e., to have the camera or cameras scan the reference adhesive tail)~~,~~ in order to calculate ~~therefrom~~ corresponding parameters on which the assessment of the applied adhesive trails are ~~is based~~ subsequently based.

[0005] Conventionally there~~Until now, it~~ was a necessity~~necessary~~ in the teaching-in of a reference adhesive trail for each camera to individually scan the adhesive trail in order to obtain camera images for all positions. When using ~~For the use of~~ three cameras, ~~this means that~~ the reference adhesive trail had to be scanned thrice in sequence and the three different sequences of images of the three cameras had to be assigned. A disadvantage with this method is that the ~~This~~

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~~is disadvantageous in that it results in the~~ parameterization of the reference adhesive trail being cumbersome and time~~time~~ consuming and can lead to high inaccuracy.

[0006] Moreover, there is a need for a method to recognize~~for recognizing~~ a structure to be applied onto a substrate using~~for~~ at least one or more cameras, and ~~which method is used~~ to monitor an application structure or adhesive trail at a high accuracy and speed while the structure~~it~~ is being applied.

Therefore an object of

[0007] It is therefore the ~~object of the~~ present invention is to provide a method for recognizing a structure to be applied onto a substrate for at least one or more cameras. The~~, which~~ method facilitates rapid start-up at a high accuracy and permits ~~/or~~ quick teach-in of the reference adhesive trail.

[0008] Moreover, ~~it is~~ an object of the present invention is to provide a method for recognizing a structure to be applied onto a substrate using~~For~~ at least one or more cameras. The~~, which~~ method monitors an application structure ~~and/~~or adhesive trail at a high accuracy and speed while the structure~~it~~ is being applied.

[0009] Moreover, ~~it is~~ an object of the present invention is to provide a suitable apparatus for carrying out the method according to the invention.

~~[0010]~~ In~~These objects are met with regard to~~ the method ~~by the features of claims 1~~ and ~~4, and with regard to the apparatus by the features of claim 28.~~

[0010] ~~In the~~ apparatus according to the invention ~~and the method according to the invention~~, a reference application structure is taught-in. In addition, ~~and~~ further applied application structures ~~and/~~or adhesive trails are compared to the reference application structure for assessment. The ~~thereof. In this context, it is irrelevant whether the~~ application facility

according to the invention (~~!~~i.e., the application facility with cameras~~,~~ or~~,~~ as a kinematic inversion) can be moved or~~,~~ the substrate can be~~is being~~ moved.

[0011] The method ~~according to the invention~~ facilitates~~,~~ by means of teaching-in a reference application structure, and ~~the~~ recording and~~/or~~ storing of the images of all cameras in a sequence of images. The cameras take ~~after by means of just~~ a single scan of said reference application structure. The single scan ~~This~~ reduces the time of the~~until~~ start-up of an apparatus because of ~~of this type to~~ a short teach-in time.

[0012] According to a method of~~according to~~ the invention for recognizing a structure to be applied onto a substrate, (e.g., preferably an adhesive line or adhesive trail) ~~, with~~ at least one camera, (e.g., in particular multiple cameras), is used ~~, whereby the applied structure,~~ during the scanning for assessment of the~~this~~ structure and ~~,~~ is processed in the form of an optical representation. Each ~~such that each~~ camera records ~~just~~ a strip of the image to form a sequence of images, and the image recording rate is increased in line with the data reduction achieved by recording only a strip of the image. An advantage is that the method ~~, is obtained an advantageous recognition method and monitoring method for a structure to be applied that~~ is highly accurate and can be fully automated.- This allows the adhesive trail to be monitored in parallel ~~and/~~or simultaneous to the application of the adhesive trail.

[0013] Furthermore, an advantage is~~Further advantageous developments are evident from the subclaims. Accordingly, it is advantageous~~ for each camera to record ~~only~~ a strip of the image to form a part of a ~~the~~ sequence of images ~~in order~~ to minimize the data to be included in a ~~the~~ calculation. Because~~Since~~ less data is~~has to be~~ included in the calculation and because of the high image recording rate, recording~~it is feasible to record comparably~~ small partial sections of the whole adhesive trail to be recorded (e.g.,~~, for example~~ between 1 mm and 3 mm) is feasible. The ~~, such that the~~ adhesive trail being a type of vector chain~~,~~ can be followed automatically in the individual images.

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[0014] Moreover, another advantage is ~~it is advantageous~~ to increase the image recording rate in line with the data reduction achieved by recording only a strip of the image. In~~, which is facilitated in~~ particular by using~~the use of~~ the partial scanning technique, ~~such that~~ a higher frame rate is attained. Thus, capturing ~~It is therefore feasible to capture~~ images synchronously and in parallel by all cameras at the same time is feasible. ~~,~~ The image recording therefore proceeds at defined fixed time intervals and is independent of ~~the~~ robot control.

[0015] According to the invention, the image strips of the individual cameras are joined to form a single image. Thus,~~ which is advantageous in that~~ the respective images of the individual cameras are assigned accordingly independent of location and can be recorded and processed synchronously. In addition, ~~this prevents~~ errors are prevented in the teach-in because~~since~~ the images of the individual cameras are always assigned with a correct time and a location.

[0016] According to a preferred embodiment, ~~per~~ each camera uses only approximately a quarter~~. 1/4~~ of the image lines ~~are used~~ as image strips, thus quadrupling~~strip and this is used to quadruple~~ the image recording rate. Moreover, an advantage of the ~~it is advantageous if the~~ parameterization of the sequence of images obtained from the reference application structure is that the results from a single image recording run of all cameras is ~~carried out~~ automatically performed by means of a one-time external indication ~~and/~~or external marking (e.g.~~for example~~ by means of a mouse click) of the reference application structure. The external marking is~~, and~~ used for comparison to an applied adhesive trail.- In particular, the robot travel path, the robot travel time, the direction, the width and the quality of the adhesive trail~~frail~~ are used for parameterization.- This simple parameterization procedure reduces the risk of maloperation or incorrect parameterization. The ~~, whereby the~~ system can be also be operated by personnel with low qualifications. ~~qualification also.~~ Thus, the~~this~~ parameterization generates a vectorization of the entire adhesive trail. The~~, whereby this~~ vectorization provides for reliable and automatic monitoring of the adhesive trail because of the high image recording rate.- In addition, the

vectorization~~this~~ results in a switch of the sensor head ~~only~~ requiring recalibration ~~and/~~or new calibration without having to teach-in ~~the adhesive trail~~ again the adhesive trail.

[0017] According to a preferred embodiment of the invention, an assessment function, in particular a fuzzy assessment is used to analyze the adhesive agent track ~~and/~~or adhesive trail. In~~, whereby in~~ particular the width of the pair of edges comprising the right and the left edge of the adhesive trail, the mean gray scale value of the projected gray scale value profile between the pair of edges, the edge contrast, and the progression of position are included in the calculation by means of the assessment function. As~~, whereby, as~~ a result, the adhesive trail can be described accurately such that the adhesive trail can be recognized automatically in a reliable fashion.

[0018] Moreover, an advantage~~it is advantageous~~ for the edge of the adhesive trail to be determined on a surrounding track ~~and/~~or orbit (e.g.~~and, in particular~~, an essentially circular track) ~~and/~~or circular line in order to capture any progression of the adhesive trail around the application facility in a defined area. The~~In this context, the~~ adhesive trail progresses within the surrounding track, which ~~that~~ can be elliptical, polygonal, or approximately circular.

[0019] According to a preferred embodiment, the center of the circular line or ~~of~~ the surrounding track essentially coincides with the site from which the adhesive emanates to form the adhesive trail. Each~~, whereby each~~ camera monitors at least one segment of the circle formed by the circular line.

[0020] Errors at the transition from one camera to the next can be reduced by having each camera monitor at least one overlapping area jointly with at least one adjacent camera.

[0021] It is particularly advantageous for the angle values of the circular line ranging from 0 to 360° ~~to~~ form a global coordinate system of the individual cameras. A ~~, whereby a~~ segment of the circular line is assigned to the images of the individual cameras.- As a result, the progression of the adhesive trail can be followed by at least one active camera, whereby

statements concerning the entire adhesive trail as well as the~~its~~ position ~~and/~~or progression of the adhesive trail can be made by relatively simple means.

[0022] According to a preferred embodiment, a first camera covers a range of angles ranging from -10° to 130°, a second camera covers a range of angles from 110° to 250°, and a third camera covers a range of angles from 230° to 10°, where~~in case~~ three cameras are being used.

[0023] Moreover, during the progression of the adhesive trail, an advantage~~it~~ is ~~advantageous~~ to ~~switch~~ automatically switch from one camera to the next when the adhesive trail progresses from the segment of a circular line of one camera via the overlapping area to the segment of a circular line of a different camera.- As a result, it is feasible to reliably follow the progression of the track ~~and/~~or position of the track, and these are predictable accordingly. Therefore, fully automatic switching between neighboring cameras can occur such that the parameterization times are reduced.

[0024] Moreover, an advantage of light emitting diode (~~it is advantageous if~~ LED) illumination means is the color that ~~of which~~ provides a suitable contrast to the color of the application structure is~~are~~ used for illumination. A ~~In this context, the~~ color of the light is selected such that, according to the principle of complementary colors, a ~~the~~ maximal contrast between the substrate and the adhesive trail results. An advantage of the invention is ~~It is advantageous~~ to use infrared LEDs or ultraviolet LEDs (UV LEDs) that . ~~. Particular advantages result from using light-emitting diodes whose particular design allows them to~~ emit red, green] and blue light, in particular upon the use of red-green-blue LEDs (RGB LEDs). ~~.~~ As a consequence of using LEDs, the sensor design can be switched to a corresponding adhesive color without further reconfiguration.

[0025] If ~~LEDs with the~~ triple colored LEDs (e.g.~~colors~~, red, green, and blue)~~,~~ are used, the most suitable ~~mixed~~ color combined can be generated for optimal contrast.

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[0026] According to a further development of the invention, the LEDs are flashed, ~~whereby,~~ in particular, by utilizing pulses of current (e.g., ranging from ~~of~~ 1.0 to 0.01 ms)~~are~~ applied to the diodes. Flashing the diodes, obtains~~in order to obtain~~ focussed images~~, in particular~~ of the adhesive trail, while the sensor scans over the substrate.

[0027] Moreover, for ~~a~~three-dimensional positional correction for the application facility is performed by means of the stereometry procedure with regard to positional tolerances of the individual components ~~and/~~or tolerances of the joining seams and provides an advantage~~, itIs advantageous~~ for the reference contour ~~and/~~or a feature to be determined by at least two cameras~~, in order to carry out a three-dimensional positional correction for the application facility by means of the stereometry procedure~~.

[0028] Another advantage is~~It is also advantageous~~ if the two cameras record the substrate, a section of the component, or one or more components in the form of a full image or large image, whereby the full images or large images of the two cameras comprise an overlapping area in a leading direction. The ~~, and whereby the~~ three-dimensional recognition of the reference contour position results~~resulting~~ in the overlapping area ~~is~~ used for gross adjustment of the application facility prior to applying the structure. Thus~~In this context~~, corresponding correction values are transmitted to the application facility ~~and/~~or the robot in order to shift the application facility's or robot's~~its~~ coordinate system for the application of the adhesive agent.

[0029] If a projection is made onto the area of the reference contour for a three-dimensional analysis, (e.g.,~~in particular~~ if one or more laser lines are applied to the substrate in the form of a projection), then the ~~a~~three-dimensional analysis of the profile with regard to the height and contour of arbitrary components can be facilitated even though this is not analyzable by common image processing without an additional projection.

[0030] An advantage of the invention is~~Advantageously,~~ the individual cameras are

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calibrated in order to assign the angle assignment of the individual cameras according to a ~~the~~ circular caliper. In ~~, whereby in~~ particular a circular arc of the calibrating device with marker points at 0°, 120°, and 240° for three cameras is used. The marker points allow~~This allows~~ a global coordinate system to be used with regard to the angle assignment for the individual cameras on the circular caliper around the application facility in order to simplify the processing by ~~the~~ software.

[0031] Moreover, the distance of the application facility from a feature of the component (e.g.,~~, for example~~ from edges of the component, or holes ~~and/~~or breakthroughs)~~,~~ can be measured in order to carry out a positional test of the applied structure. A ~~In this context, in particular, a~~ line-shaped gray scale value scan ~~and/~~or line-shaped calipers are used for distance measurement such that any number of reference markers can be placed along the circular arc of the calibrating device. Image~~, whereby the image~~ processing is not exclusively limited to the camera image, in which the adhesive trail test is carried out.- It is therefore not necessary for the adhesive trail and suitable reference features to be visualized in the same camera image, which has a~~is of advantage in~~ particular advantage with regard to the parallel processing of three camera images.

[0032] The present invention also provides an apparatus for recognizing a structure to be applied onto a substrate, preferably an adhesive line or adhesive trail, ~~for carrying out a method according to the invention according to claim 1 and/or 4,~~ whereby at least one illumination module and one sensor unit are provided.- The sensor unit includes ~~is made up of~~ at least one or more cameras that are ~~provided and~~ arranged around the facility for applying the structure. Each camera is~~, and each are~~ directed at the facility for applying the structure.- By this means ~~it is feasible for~~ the travel path of the facility over a substrate ~~and/~~or a travel path of the substrate relative to the application facility to be monitored at all times in all directions by means of directing the cameras at the application facility is feasible.

[0033] An advantage is if~~If~~ the axial longitudinal axis of the individual cameras essentially intersects (e.g., in the direction of view or along~~,~~ the axial longitudinal axis of the application facility), ~~, it is advantageous according to a development of this type that~~ a narrow area around the application facility can be monitored at suitable resolution and high image recording rate.

[0034] According to a preferred embodiment, individual cameras, in particular 3 cameras, are arranged at equal distances from each other in the direction of the circumference.

[0035] The ~~Advantageously, the~~ individual cameras are circuited such that the images of the cameras are stored in a sequence of images such that these images can be recorded synchronously and in parallel as well as in an assigned fashion.

[0036] According to a development of an invention, one or more cameras form a circular caliper whose center is formed by the application facility of the structure. Thus~~In this context~~, one or more circular calipers can be used to ~~that~~ facilitate the determination of the edge of the adhesive trail on a circular line.

[0037] According to a preferred embodiment, the individual cameras comprise an overlapping area of at least 10° each relative to the adjacent~~next~~ camera.- This overlapping area facilitates fully automatic switching between neighboring cameras when the adhesive trail progresses from the monitoring area of one camera to the next. Because~~, since~~ the selection of the camera is not bound to the robot position or a time component, but rather always refers to the actual inspection results. For instance, the insepection results are ~~, i.e. is~~ based on the arrangement,~~ on~~ the orbit, the ~~and/or~~ circular line of the circular caliper, ~~and/~~or the global coordinate system formed thereby.

[0038] Moreover, an advantage is ~~it is advantageous~~ for the illumination module to

comprise light emitting diodes (~~be made up of~~ LEDs), in particular infrared LEDs, ultra-violet LEDs (UV LEDs) or Red-Green-Blue LEDs (RGB LEDs).

[0039] Moreover, an~~it is of~~ advantage is the ~~to~~ use of a calibrating disc with individual form elements for calibrating the individual cameras for the assignment of the angle assignment. The~~, whereby said~~ form elements comprise, in particular, an angle distance of essentially 10°, which~~°. This~~ allows for assignment of a ~~the~~ scaling factor, an angle assignment, and a center and a ~~as well as~~ radius of the search circle for the individual cameras.- According to the invention, the calibrating disc comprises at least three marker sites that are arranged in a circular arc of the calibrating disc (e.g. ~~of~~ essentially located at 0°, 120 °, and 240 °), in order to calibrate the three cameras.

[0040] If a projection facility projecting one or more features (e.g., in particular strips)~~,~~ onto the substrate for the three-dimensional analysis is provided on the application facility, arbitrary components can be used for correction ~~and~~/or adjustment of the application facility prior to applying the structure.

[0041] According to a preferred embodiment, the projection facility emits one or more laser lines for a three-dimensional profile analysis.- Arranging at least two projection facilities around the application facility facilitates a gap-free three-dimensional analysis around the application facility. Means of image processing, whereby the analyses of a sealing agent height and a sealing agent contour, as well as a position and a width, can be performed~~carried out~~ according to the principle of triangulation ~~by means of image processing~~.

~~[0043]~~ Advantages~~Further advantageous developments of the invention are the subject of the remaining subclaims.~~

[0042] ~~Advantageous developments~~ of the invention shall be illustrated in an exemplary fashion by means of the following drawings.

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[0043] Figure 1 illustrates~~shows~~ a schematic side view of an apparatus according to the invention for application and monitoring of an adhesive trail.

[0044] Figure 2 illustrates~~shows~~ a perspective view of an ~~the~~ apparatus according to the invention of Figure 1.

[0045] Figure 3 illustrates a ~~shows the~~ travel path of the apparatus according to the invention for application and monitoring of an adhesive trail.

[0046] Figure 4 illustrates~~shows~~ another travel path of the apparatus according to the invention with regard to ~~the~~ switching of a~~the~~ relevant camera.

[0047] Figure 5 is a view of a single image composed of three image strips from three cameras for online monitoring.

[0048] Figure 6 illustrates the principles of the design of the software.

[0049] Figure 7 illustrates~~shows~~ a schematic view of a calibrating device according to the invention for calibrating ~~the~~ individual cameras of an ~~the~~ apparatus according to the invention for recognizing a structure to be applied onto a substrate.

[0050] Figure 8 illustrates~~shows~~ a top view onto a ~~the~~ substrate with an ~~the~~ adhesive trail applied with regard to monitoring the application.

[0051] Figure 9 illustrates ~~shows~~ a top view with regard to analysis of the profile.

~~[0054] In the following, the design of the apparatus according to the invention for recognizing a structure to be applied onto a substrate is illustrated according to Figures 1 and 2.~~

[0052] Reference number 10 illustrated in Figure 1 indicates ~~the~~ schematically an~~shown~~

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apparatus for the application and recognition of an adhesive trail 20. ~~,~~ In the center of the apparatus ~~according to the invention~~ is arranged an application facility 11 by means of which an adhesive trail 20 is applied onto a substrate 30 ~~and/~~or onto a sheet of metal 31 ~~30~~ proceeding from right to left in Figure~~.~~ 1. Three cameras 12, 13, 14 are arranged at equal distances from each other in a circle around the application facility 11, wherein~~it,~~ each camera ~~of which~~ is directed at the application facility 11.- As is evident from Figure 1, the axial longitudinal axes of the three cameras 12, 13, 14 intersect the axial longitudinal axis of the application facility 11 ~~just~~ below the substrate 30 such that the focus of the individual cameras 12, 13, and 14 are ~~is~~ arranged ~~right~~ around the area of the application facility 11, in particular, on a circular line.

[0053] In the inspection of the adhesive, either the application facility 11 with the cameras 12, 13, and 14 or the substrate 30 is moved. The ~~, whereby the~~ adhesive trail 20 is simultaneously applied to the substrate 30 by means of the application facility 11, ~~and~~ whereby the cameras 12, 13, 14 monitor the applied structure. Thus,~~For this purpose, it is feasible to move~~ either the application facility 11 with the cameras 12, 13 and 14 or the substrate 30 can be moved, in~~In~~ order to apply the adhesive trail 20 onto the substrate 30 such as to follow a desired progression.- By this means, the moving cameras 12, 13, and 14 ~~being moved along~~ can monitor, independent of the path of travel, the adhesive trail 20~~frail~~ at the time the adhesive trail 20~~it~~ is being applied.- In Figure~~.~~ 2, the adhesive trail 20 progresses from left to right and is indicated by a continuous line. The intended progression of the adhesive trail 20 is indicated by a dashed line to the right of the application facility 11.

[0054] Figure 3 illustrates~~then shows~~ the progression of the adhesive trail 20 as indicated by arrows 21 and 22, whereby the direction ~~and/~~or field of view of the three individual cameras 12, 13 and 14 are~~is~~ shown in three sites 23, 24 and 25. ~~,~~ The field of view 23, 24, and 25 of the three individual cameras 12, 13 and 14~~each~~ is indicated by a rectangle drawn with a continuous line24, a rectangle drawn with widely dashed lines 23, and a rectangle drawn with narrow dashed lines 25. ~~,~~ As shown in~~is evident~~ from Figure 3, the direction of the individual fields of view 23,

24, and 25 of the cameras 12, 13 and 14 remains constant at all times whereby only the whole apparatus is moved along the adhesive trail 20 as indicated by arrows 21 and 22.

[0055] Figure 4 illustrates~~shows~~ another progression of an adhesive trail 20, whereby a field~~it is indicated in each case, which held~~ of view is active (~~,~~ ~~i.~~e.g., shown as "aktiv") 27. The ~~which~~ camera 12, 13 and 14 having the corresponding active field of view is shown as an "aktiv" ~~a~~ rectangle 27 ~~is active~~ while traveling along the adhesive trail 20.

[0056] Figure 5 illustrates~~then shows~~ three image strips 32, 33, and 34 that ~~which each~~ represent a relevant section ~~and/~~or strip of an image of the three individual cameras 12, 13 and 14 (shown in ~~of~~ Figure 1). Each camera12, 13 and 14 ~~. According to the method of the invention, each camera~~ records ~~just~~ a strip of the image in order to reduce the amount of data accordingly such that the recording rate can be increased.- These individual image strips 32, 33, and 34 of the three cameras 12, 13 and 14 are then joined into an image. The ~~, whereby the~~ image recording occurs at defined fixed time intervals and is independent of the robot control of the application facility 11. ~~.~~ For example, the cameras 12, 13 and 14 only record a strip of the image having an image height of approximately 100 pixels (e.g., 100 image lines is used) ~~, whereby~~ instead of an image height of 450 pixels. ~~an image height of approx. 100 pixels (100 image lines) is used.~~ By means of this partial scanning technique (~~,~~i.e., partial reading-out of the image recording chip)~~,~~ only small data streams are generated such that the image recording rate can be increased several-fold. Therefore, ~~accordingly. It is therefore feasible in~~ the data analysis simultaneously captures~~to capture~~ the three image strips that are arranged one below the other~~images~~ of the individual cameras 12, 13 and 14 synchronously and in parallel and ~~therefore simultaneously and~~ then joins ~~join~~ them into a single image. ~~, whereby the three Image strips are arranged one below the other.~~ As a result, the three ~~images, i.e. the three~~ image strips, are correctly arranged and assigned with regard to a location and a time~~lime~~ relative to each other and without delay ~~further ado, and~~ can be processed accordingly. The ~~This~~ specific image recording technique ~~therefore~~ facilitates simultaneous and parallel recording of individual

camera 12, 13 and 14 that are stored as a sequence of images. Thus, the structure can be scanned~~images, whereby it becomes feasible to scan this structure just~~ once during the teach-in of a reference application structure~~, whereby the images of all cameras are stored in a sequence of images~~.

[0057] Once the images of the three cameras 12, 13 and 14 are stored in a sequence of images, a parameterization of the ~~this~~ reference track is carried out as the subsequent step of teaching-in the reference adhesive trail. A ~~The~~ robot travel path, a robot travel time, a direction, a width, and a quality of the adhesive trail 20 are utilized to determine~~used in~~ the parameterization. A ~~This results in a~~ type of vector chain for the adhesive trail 20 results, which allows a ~~to attain the~~ high image recording rate to be attained via ~~and~~ comparably short partial sections (e.g., between 1 and 3 mm).- Vectorization has another advantage, in that, the adhesive trail 20, being in the form of a vector chain, can be stored in a camera-transcending global coordinate system.

[0058] As shown in ~~is evident from~~ the bottom strip 34 of Figure 5, a circular line is arranged around the center of the application facility 11, and ~~in the form of a circular line, whereby the~~ two edge points 21 and 22 of the adhesive trail 20 are arranged on the circular line. The ~~This~~ circular line is subdivided into a plurality of angles to provide overlapping areas of the individual cameras 12, 13 and 14 to facilitate a gapless coverage around the application facility 11. A ~~such that a~~ range of angles from -10° to 130° is assigned to a first camera. A~~, a~~ range of angles from 110° to 250° is assigned to a second camera, and a range of angles from 230° to -10° is assigned to a third camera. A ~~such that gapless coverage around the application facility 11 by overlapping areas of the individual cameras is facilitated. From this results a~~ global coordinant~~coordinate~~ system results for the three image strips, which ~~that~~ can be provided as either ~~to be~~ Cartesian coordinants or polar coordinants.

[0059] If the adhesive trail 20 progresses out of the field of view 23, 24 and 25 of a

camera, the adhesive trail 20~~frail~~ is transiently in the overlapping area of the ranges of angles of the adjacent two cameras.- If the adhesive trail 20 then progresses from the segment of the circular line of the one camera via the overlapping area to the segment of the circular line of another camera, an automatic switch is made from the one camera to the other camera.- This is illustrated~~shown,~~ in ~~particular, in~~ Figure 4 by means of the active fields of view 27 of the individual cameras 12, 13 and 14.

[0060] The ~~advantages mentioned above are attained by the~~ individual cameras 12, 13 and 14 form ~~forming~~ a circular caliper whose center is formed by the application facility 11, whereby the search for the edges 21, 22 of the adhesive trail 20 proceeds on a circular line directly around the application facility 11. The~~. For this purpose, it is essential that the~~ individual cameras 12, 13 and 14 are essentially directed at the application facility 11 such that ~~, whereby~~ the axial longitudinal axes of the individual cameras 12, 13 and 14 intersect the longitudinal axis of the application facility 11.

[0061] A teach-in run ~~and/~~or a teach-in of a reference adhesive trail is described~~illustrated~~ in the following paragraphs .

[0062] The teach-in process of the reference adhesive trail can be started by a ~~the~~ user by means of a mouse-~~-~~click by selecting a ~~on the~~ track that~~which~~ indicates the position of the adhesive trail 20. ~~,~~ This is sufficient for fully automatic recognition of position and direction of the adhesive trail 20 in the subsequent camera images because~~, since~~ the image recording rate is sufficiently high and the individual images are recorded very shortly after one another (e.g.,~~, for example~~ every 1 mm to 3 mm). ~~,~~ From the starting point, the adhesive is scanned image by image, whereby the adhesive trail position and the adhesive trail angle detected in the current image are used as *a priori* knowledge for the upcoming image. ~~as a priori knowledge.~~ The fact that the track radii usually exceed 20mm facilitates fully automatic capture of the adhesive trail 20 without a human ~~being~~ having to ~~determine and/or~~ assess the image ~~and/~~or the position of the

adhesive trail 20. ~~,~~ As a result, the search area can be limited which allows, by means of the high image recording rate, a determination of ~~to calculate~~ where the adhesive trail 20~~trail~~ will essentially progress to in the following image.

[0063] Figure 6 **[NEEDS TO BE TRANSLATED FOR IS IN GERMAN]** illustrates~~shows~~ the principles of the design of the software, whereby the teach-in run ~~and/~~or teach-in run generates the image sequence. The image sequence,~~, which~~ in turn, facilitates the automatic parameterization.- This parameterization can be pre~~pro~~-set by the user, if applicable, and is used together~~jointly~~ with a progression file for inspection of an applied adhesive trail 20 during the inspection run.

[0064] The online monitoring of an applied adhesive trail 20 is described~~shall be illustrated briefly~~ in the following paragraphs. ~~,~~ The application facility 11 (shown in Figure 1) applies the adhesive trail 20 onto the metal sheet 31~~30~~, whereby the application facility 11~~ii~~ is moved together~~jointly~~ with ~~the~~ cameras 12, 13 and 14 over the metal sheet 31. ~~30.~~ However, a kinematic inversion~~Inversion~~ is also feasible, for instance~~i.e.~~ the metal sheet 31 is ~~30 being~~ moved and the application facility 11, including~~with~~ the cameras 12, 13 and 14, is~~being~~ arranged in a ~~to be~~ fixed ~~in~~ position.– The applied adhesive trail 20 is determined and analyzed synchronously and in parallel by the cameras 12, 13, 14. The cameras 12, 13, and 14 are on the circular line of the circular caliper (shown in ~~illustrated according to~~ Figure 5), whereby each camera 12, 13, and 14 records only a strip of the image. The strips of images are joined~~and joins these~~ into a single image that ~~to~~ form a sequence of images. Thus, the ~~The~~ image recording rate is increased in accordance with the data reduction attained by each camera 12, 13 and 14 recording only a strip of the image. The ~~, whereby the~~ individual image strips in the joint image facilitate the synchronous and parallel as well as simultaneous capture of the three camera images. The ~~, and whereby the~~ individual images of the three cameras 12, 13 and 14 can be assigned directly as a function of location.- As a result, online monitoring of the adhesive trail 20 is feasible in real-time and ~~is feasible that~~ achieves high accuracy at high travel speeds due to the

high image recording rate both in teaching-in a reference adhesive trail and in the inspection of the applied adhesive trail 20. The ~~. In this context, the~~ information concerning the adhesive trail 20 in the adhesive search area, the angle assignment of the sensor, the adhesive assessment, the robot travel path, and the robot travel time are summarized in a progression list.

[0065] According to an embodiment of the present invention, an assessment function (e..g, in particular a fuzzy assessment)~~,~~ can be used to find the edges of the adhesive trail 20. In~~in~~ order to determine and assess the adhesive trail 20, the following parameters described below are included in the calculation of a fuzzy assessment.

[0066] A width of a ~~Width of the~~ pair of edges (e.g., an edge 1: a left edge of the adhesive trail; an~~,~~ edge 2: a right edge of the adhesive trail), a mean gray scale value of the projected gray scale value profile between the pair of edges, an edge contrast (e.g., a geometric mean of ~~the~~ amplitudes of the two edges), and a progression of position (e.g., directed deviation of a ~~the~~ center between the~~tie~~ two adhesive edges from a ~~the~~ center of the search area, in pixels). By means of this plurality of parameters~~,~~ and the use of the fuzzy assessment function, the adhesive trail 20 can be ~~described very accurately such that the adhesive frail can be recognized~~ automatically recognized in a reliable fashion and described very accurately.

[0067] The illumination module (not shown) for ~~here) far~~ the apparatus according to the invention comprises light emitting diodes (~~is made up of~~ LEDs), in particular infrared LEDs, ultra-violet LEDs (UV LEDs) or Red-Green-Blue LEDs (RGB LEDs). ~~,~~ In order to attain a high contrast in an image recording, the LEDs can be flashed. For instance~~, i.e.~~ short, strong pulses of current on the order of 1.0 to 0.01 ms can be applied to the diodes. Thus, the~~In this context,~~ light-emitting diodes are capable of emitting light of various colors. The advantage is ~~are particularly advantageous such~~ that a ~~the~~ sensor design can be switched to other types of adhesives or ~~adhesive and/or~~ colors of adhesives without reconfiguration.

[0068] Figure 7 illustrates~~shows~~ a calibration facility 40 in the form of a circular

calibrating disc. The calibration facility 40 assigns ~~in order to assign to~~ the individual cameras 12, 13 and 14 a ~~their~~ scaling factor, an~~their~~ angle assignment, and a ~~the~~ center as well as a ~~the~~ radius of a ~~the~~ search circle.- The calibrating disc consists of individual form elements 41 (e.g. shown as ~~and/or~~ dots) ~~41~~ that are arranged on a circular line ~~and~~ at an angle distance of approximately 10° ~~essentially 100.~~ Moreover, marker sites 42 are arranged at an equal distance from each other in order to calibrate three cameras 12, 13 and 14. ~~,~~ A compensation calculation is used to calculate from the coordinates of the centers of the individual dots, on the one hand, the scaling factors of the individual cameras 12, 13 and 14 and, on the other hand, the center as well as the radius of the search area.- The marker sites at angles of 0°, 120°, and 240° in the global coordinate system allow the angle assignment and the corresponding fields of view of the individual cameras 12, 13 and 14 to be determined.- The field of view of the individual cameras 12, 13 and 14 is indicated, in particular, by the three rectangles 43, 44, and 45 (shown in Figure 7). The ~~, whereby the~~ form elements 41 can correspond to the circular line of the circular caliper for detection of the adhesive trail 20.

[0069] Figure 8 illustrates~~shows~~ the application facility 11, whereby the strips 31, 32, and 33 around the application facility 11 each are shown by dashed lines that ~~and~~ represent the read-out area of the individual cameras 12, 13 and 14. Two active cameras monitor the adhesive trail 20, such that the ~~. The~~ adhesive trail 20 is monitored in the overlapping area of the strips 32 and 33. ~~such that these two cameras are active.~~ If the progression of the adhesive trail 20 relative to the application facility 11 changes, only one~~, if applicable,~~ of the cameras 12, 13 and 14 becomes active, and~~whereby~~ an essentially circular caliper (not shown) that is arranged to be concentric around the application facility 11 is used ~~for this purpose~~.

[0070] According to this embodiment, the circular caliper is formed by multiple cameras 12, 13 and 14 that are arranged around the application facility 11, but, in particular, can be attached at a different radius from the center of the application facility 11. For an inspection of an application structure ~~and/~~or adhesive trail 20, the cameras 12, 13 and 14 are directed at a

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circle ~~and/~~or circular line whose center coincides with the center of the application facility 11. The optical detection of the adhesive trail 20~~as illustrated above~~ then proceeds on this circular line.

[0071] Figure 9 illustrates a ~~The~~ three-dimensional profile analysis by means of a projection ~~is described according to Figure 9, in order~~ to provide for a positional correction of the application facility 11. ~~,~~ For reasons of clarity of presentation, Figure~~fig.~~ 9 illustrates~~again shows only~~ two camera fields of view 51, 52 indicated by the dashed lines.- In the overlapping area of the two camera fields~~holds~~ of view 51, 52 are shown a plurality of laser lines 60 that are used for profile analysis with regard to the width and contour of structure lines. the laser lines are also used ~~and~~ for generation of so-~~called so~~ft contours. The laser lines 60 are generated by a projection facility that can, for example, be arranged on the optical sensor with three cameras 12, 13 and 14. ~~,~~ Moreover, the projection facility can also~~just as well~~ be arranged directly on the application facility 11.- The sensor with the three cameras 12, 13 and 14 is shown schematically by the circle 70.- The laser lines 60 ~~and/~~or laser strips projected onto the component 30 ~~and/~~or metal sheet 31~~30~~ highlight contours on the component that cannot be used for three-dimensional analysis by conventional image processing.- Artificial features are generated by means of the laser lines 60~~tines~~ on the component and can subsequently be analyzed by means of image processing utilizing~~according to~~ stereometry.- Thus, Figure 9 illustrates~~shows~~ the principle of three-dimensional positional recognition prior to the application of a sealing agent where~~in case~~ no hard, analyzable features are present.

~~[0075] Therefore, a method and/or an apparatus for recognizing a structure to be applied onto a substrate, preferably an adhesive line or adhesive trail, with at least one camera, in particular multiple cameras, is described. In this context, the teach-in of a reference application structure is carried out by means of just a single scan of said reference application structure such that the images of all cameras are stored in a sequence of images.~~

~~[0076] Moreover, a method for recognizing a structure to be applied onto a substrate is described, whereby the applied structure is processed as an optical representation during the scan for assessment of the structure such that each camera records just a strip of the image to form a sequence of images and the image recording rate is increased in line with the data reduction achieved by recording only a strip of the image.~~

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METHOD AND APPARATUS FOR RECOGNIZING A STRUCTURE TO BE APPLIED ONTO A SUBSTRATE WITH MULTIPLE CAMERAS

ABSTRACT OF THE DISCLOSURE

A method and apparatus are provided for automatic application and monitoring of a structure to be applied onto substrate. A plurality of cameras positioned around an application facility are utilized to monitor the automatic application of a structure on a substrate by means of a stereometry procedure. Three-dimensional recognition of a reference contour position results in the overlapping area to be used for gross adjustment of the application facility prior to applying the structure.